

# Chapter 3

## The Impact of EV Charging on the System Demand

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### 3.1 Introduction

The technical specifications of an EV fleet, i.e., EV technology (pure battery or plug-in hybrid) and their energy consumption, affect the energy requirements of EV charging. Moreover, the charging needs of EV are determined by random variables, such as their mobility, in terms of daily traveled distances and the EV owner driving profiles. This implies that deterministic methodologies for the energy analysis of EV operation are inefficient and the stochastic behavior of the EV needs to be taken into account. In this chapter, a stochastic simulation platform is presented providing the ability to define the additional EV charging demand. The allocation of EV demand within a day depends on the connectivity of EV (the time and duration of plug-in period) and the availability of charging infrastructures (home, workplace, public charging, etc.). These two factors determine the changes in the daily system demand and are case sensitive. In this chapter, five EU countries (UK, Germany, Spain, Portugal, and Greece) are analyzed, in order to obtain representative conclusions regarding the impact of EV on the system demand curve. The methodology and the results presented in this chapter can be used for the development of new business models, as well as control and management architectures for EV electrical grid integration, as analyzed in Chaps. 4 and 8.

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## 3.2 Identification of EV Demand

This section aims to identify the additional demand of EV charging considering EV technical specifications and traffic pattern. Figure 3.1 shows the stochastic EV demand simulation methodology used to model the energy requirements of an EV fleet taking into account all the parameters defining an EV charging process.

The set of parameters can be separated into two subsets as follows:

### Constant Parameters

1. EV penetration level
2. Charging station technologies (mode 1, 2, and 3)
3. Availability of charging (home, home/workplace)
4. Charging losses
5. Charging policy (Dumb, Dual-tariff, and Smart Charging, V2G)

### Probabilistic Parameters

1. Classification of EV (PHEV, BEV, L7e,M1,N1,N2)
2. Daily travel distance
3. EV connectivity (return time)

These parameters are presented in detail in the following paragraphs.

### 3.2.1 EV Penetration Level

The number of simulated EV depends on the forecasted EV sales for each country. Assuming that vehicle sales are proportional to population changes, the future sales trend for all European countries' displays is increasing. Considering various key factors, such as technological development in batteries, fuel prices, investments on charging infrastructures, etc., three different EV sales scenarios can be identified [1]:

- Scenario 1: The most likely to occur
- Scenario 2: More optimistic than the one likely to occur
- Scenario 3: Very aggressive EV uptake

Figure 3.2 illustrates the expected EV deployment level for the three scenarios, as a percentage of the total vehicle sales. In the realistic scenario, it is expected that EV sales will amount for 15% of total vehicle sales in 2030, while in the optimistic scenario this EV share is almost double. In the very aggressive scenario, half of the vehicle sales in 2030 is assumed to be electric vehicles.

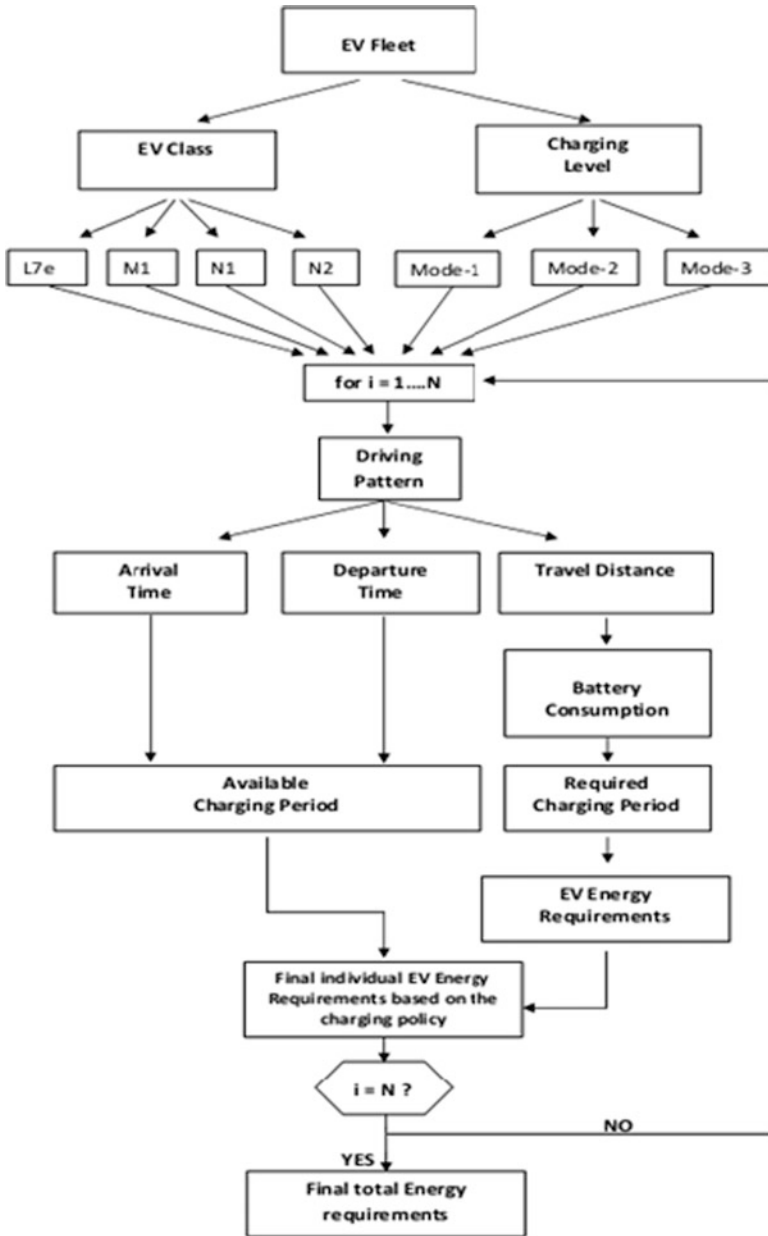


Fig. 3.1 Stochastic model for identifying the additional EV charging demand

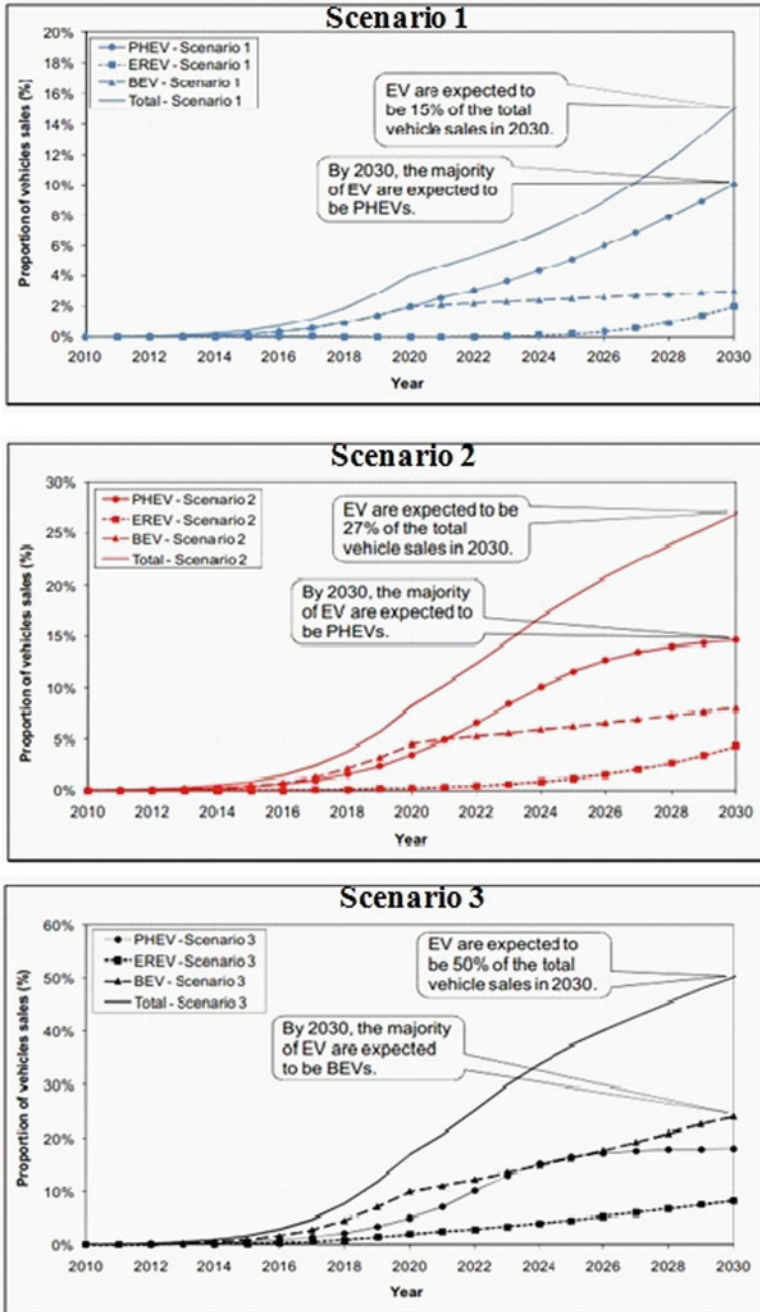


Fig. 3.2 EV deployment scenarios [1]

**Table 3.1** Descriptions of EV classification and battery capacity

Type		Battery capacity (KWh)		
		Mean	Min	Max
L7e	BEV	8.7	3	15
M1	BEV	28.5	10	72
	PHEV	12.9	4	22.6
N1	BEV	23	9.6	40
	PHEV	12.9	4	22.6
N2	BEV	51.2	51.2	120

### 3.2.2 Classification of EV

EV can be classified into two categories depending on the type of engine:

- The plug-in hybrid EV (PHEV)
- The pure battery EV (BEV)

Pure battery EV can be further subdivided into several categories according to their technical characteristics as defined by the European Commission’s official “Mobility and Transport: Vehicle Categories” document [2]. In this chapter, the categories examined are limited to the following ones, which are expected to dominate the vehicle market sales:

- L7e: small city purpose vehicles.
- M1: 4-seater passenger vehicles.
- N1: carriage of goods with a maximum laden mass of less than 3,500 kg.
- N2: maximum laden mass of 3,500–12,000 kg for commercial purposes.

Each type of EV has specific battery capacity ranging between a minimum and a maximum value. For simulation purposes, the battery capacity is expressed by a normal distribution with a mean value and a standard deviation as shown in Table 3.1. Exceptionally, a compound exponential distribution is considered for the EV type N2.

### 3.2.3 Daily Travel Distance

This parameter expresses the daily distance covered by an EV between two successive charging cycles. The daily travel distances depend highly on the purpose of EV usage. For example, during weekdays, vehicles are used mainly for working purposes, thus the distance profile exhibits approximately the same pattern. During weekends, vehicle mobility is reduced and users have the tendency to travel longer distances at different hours during the day. Moreover, since the daily travel distances depend on the habits in each country, a different profile is considered for each country studied.

**Table 3.2** Models for home/  
multiple connections

	Charging procedure
Model 1	75 % Home–25 % home/work
Model 2	50 % Home–50 % home/work
Model 3	25 % Home–75 % home/work

### 3.2.4 Battery Consumption

By defining the total traveled distance, the corresponding amount of charging energy can be calculated. The ratio between energy consumption and traveled distance (kWh/km) depends on the driving speed, road and weather conditions, etc. These parameters are highly variable and thus an average value (kWh/km) can be implemented for EV analysis purposes.

### 3.2.5 Required Charging Period

This parameter specifies the minimum time period during which the EV must remain plugged-in, in order to be fully charged. This charging period is defined by the EV usage and the maximum charging power of the available charging infrastructures.

### 3.2.6 Availability of Charging

Different scenarios can be simulated for the availability of charging:

- Charging after last trip (home charging): Since the electrification of transportation remains at an initial stage, the number of charging points will be limited. Thus, most of the EV owners will not have the ability to charge their EV anywhere, but mainly at their home private charging posts.
- Charging when a (public or private) charging point is available: In the previous scenario, the EV owner will charge his EV only when returning home. In this scenario, an EV owner has also the ability to charge his EV away from home, for example, in a workplace. This requires installation of charging points at various private or public areas. Since it is not possible to define the exact number of EV that will be charged at home (workplace), different charging patterns should be adopted (Table 3.2).
- Charging when the battery state of charge is lower than a desired level: The average traveling distance of an EV exceeds 100 km based on current technologies. When the daily traveling distance is limited, for example, in urban areas it may be less than 30 km, then there is a possibility that the owner will not plug in his EV daily, but only when necessary. In this scenario, it is assumed that an EV owner will charge his EV only when the battery state of charge is lower than a threshold, typically 40%.

**Table 3.3** Percentage of available charging infrastructures per EV type [1]

Type		Charging infrastructure (%)		
		Mode 1	Mode 2	Mode 3
L7e	BEV	90	10	0
M1	BEV	85	10	5
	PHEV	85	10	5
N1	BEV	85	10	5
	PHEV	85	10	5
N2	BEV	0	80	20

### 3.2.7 Charging Station Technologies

This parameter determines the maximum power flow between the EV and the power grid which depends on the line power capacity of the charging infrastructure. The power level of charging affects also the duration of the charging cycle. It is assumed that at the end of each charging cycle, the battery must be fully charged (SOC = 100%).

Three different charging modes have been adopted, namely, normal (Mode 1), fast (Mode 2), and dc (Mode 3), based on the IEC 62196 and IEC 61851 standards. The selection of the charging mode for each specific EV is probabilistic and depends on its type. For instance, the connection of type N2 with a battery capacity between 51.2 and 120 kWh at a normal charging point is not realistic. Table 3.3 shows the percentage of available charging infrastructures per each EV type which are considered in this analysis.

### 3.2.8 Charging Losses

This parameter expresses the losses of AC/DC power conversion from the grid to the DC charging of the EV batteries and vice versa, due to the power electronic interfaces. In the present simulations, these are considered equal to 10–15% of the total energy demand.

### 3.2.9 Charging Strategy

The assessment of the impacts of EV penetration in power systems should take into account the charging strategies, distinguished as follows:

- **Dumb Charging:** This is the unplanned “plug and play” connection of electric vehicles into the grid, typically after the last trip of the day or when a charging point is available.

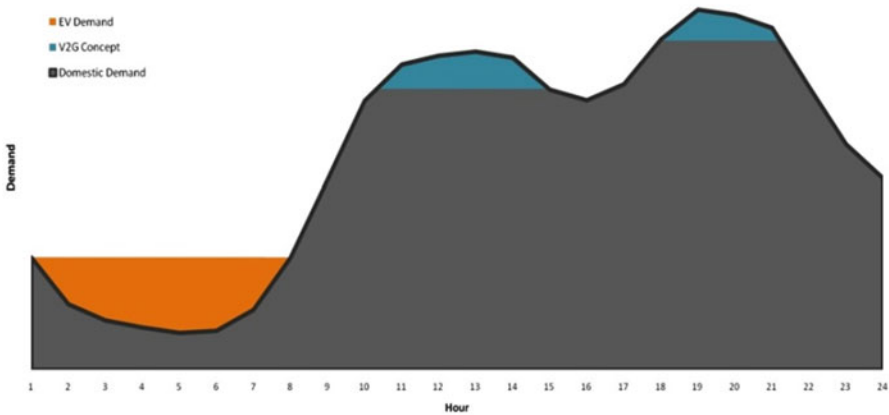


Fig. 3.3 Smart charging concepts

- **Multiple Tariff Charging:** This is the normal market way to manage energy demand. Cheaper energy tariffs are implemented at specific hours to shift demand to off-peak hours.
- **Smart Charging:** This scenario has a “valley-filling” effect, as shown in Fig. 3.3. EV charging load is shifted from peak to off-peak periods. Typically, EV mobility during off-peak hours is limited and this allows effective charging management.
- **Smart charging:** This can be considered as an extension of Smart Charging. In this strategy, bidirectional power flow exists between the EV and the power grid. It is based on the fact that average daily EV mobility lasts only 2–4 h and the respective energy requirements are only a fraction of their battery capacity. The excess battery power can be utilized during peak hours as a source of energy or for the provision of ancillary services to the grid, thus contributing to a more stable grid operation.

### 3.3 EV Impacts on System Demand

In this section, the impacts provoked by the additional EV charging load on the demand diagrams of selected countries are evaluated utilizing the methodology developed in Sect. 3.2. Five different European countries, namely, Germany, UK, Spain, Portugal, and Greece, are analyzed considering the individual charging specifications for each study case. The various charging strategies (i.e., dumb, multi-tariff, and smart charging) are simulated and the results are utilized to evaluate in a quantitative way the expected impacts of each strategy.



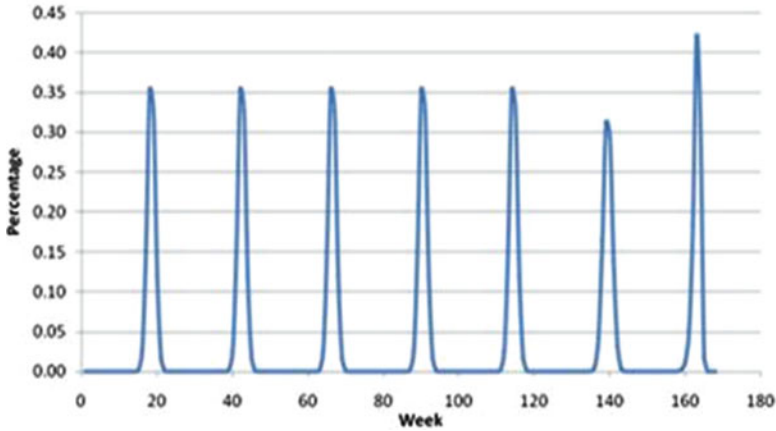


Fig. 3.4 Profile of time of return from last journey of the day (Germany)

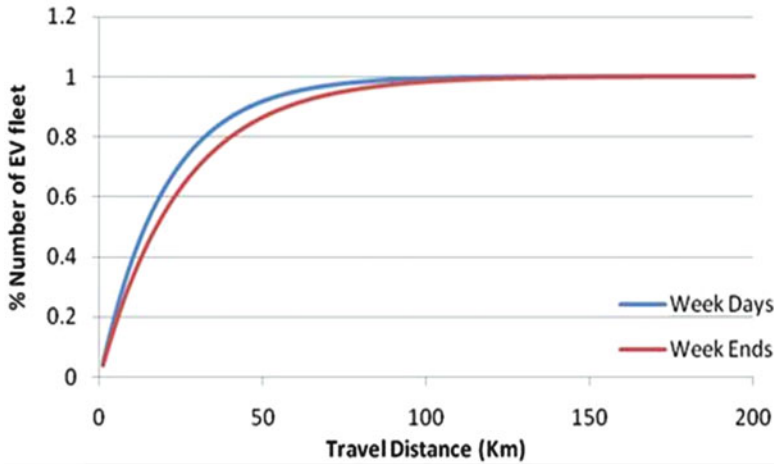


Fig. 3.5 Distances traveled per day on weekdays and weekends (Germany)

### 3.3.1 Germany

The traffic pattern for Germany is assumed to follow the normal distribution, as presented in Fig. 3.4 [3]. This analysis is performed on a weekly basis where the traffic profile is described by the same distribution function for the weekdays, and a different one for the weekends.

Figure 3.5 presents the cumulative probability function of traveling certain distances (km) daily. Due to the reduced mobility in weekends compared to weekdays, two separate functions are considered. It can be seen that the largest percentage of drivers (95%) travels less than 75 km daily. For simulation purposes,

the mean value of the distribution density function for 95% of EV is taken equal to 18 km for weekdays and 24 km for weekends. The remaining 5% of EV is characterized by long travel distances and is simulated by a normal distribution. Since this part of EV fleet is small, its influence on the total results is limited.

In the following, the impact of electric vehicles for 2020 is examined. For the Base Load Demand, the forecast scenarios of the European Union [4] are used. For Germany, a total increase of 7.3% on base load is considered for this time horizon.

### 3.3.1.1 Dumb Charging

Dumb charging implies home connection to the grid after the last trip of the EV. The daily charging requirements for the three scenarios are displayed in Fig. 3.6. In the first EV penetration scenario, the daily EV peak demand is approximately 510 MW. This is doubled (1,020 MW) in the second one and quadrupled (2,115 MW) in the aggressive scenario 3. The additional energy demand for the three scenarios is 1,732 MWh, 3,520 MWh, and 7,224 MWh, respectively.

There is a small difference between the traffic patterns of weekdays and weekends. During weekends, there is a limited use of vehicles and the mobility of EV is reduced to 70%. On the other hand, weekend days are characterized by special traffic patterns and longer travel distances.

The impact of EV fleet on the total system demand is shown in Fig. 3.7. The profile of the EV charging demand is highly dependent on the time of return from the last journey of the day. During winter time, home arrival normally coincides with increased domestic consumption; thus, the EV demand coincides with the network peak load. As the number of EV increases, the impact of the additional charging is larger and thus the daily peak increases proportionally for the three penetration levels, i.e., 70,375 MW (+0.7%), 70,885 MW (+1.5%), and 71,980 MW (+3%). During summer period, the system demand curve is characterized by a peak demand during midday hours. The additional EV load increases the daily load during afternoon hours, but it does not affect the system peak demand.

#### Dumb Charging with Battery SOC Threshold

A large portion of the EV fleet exploits a small part of its battery capacity during a day. Thus, another scenario is examined, where EV owners charge their vehicles when the state of battery is lower than 40%. Figure 3.8 presents the additional EV demand for the three penetration scenarios. This is reduced by more than 50% compared to simple dumb charging. This can be explained by the small average daily travel distance, which results in limited daily energy consumption. The additional energy requirements are now 1,148 MWh, 2,434 MWh, and 4,943 MWh.

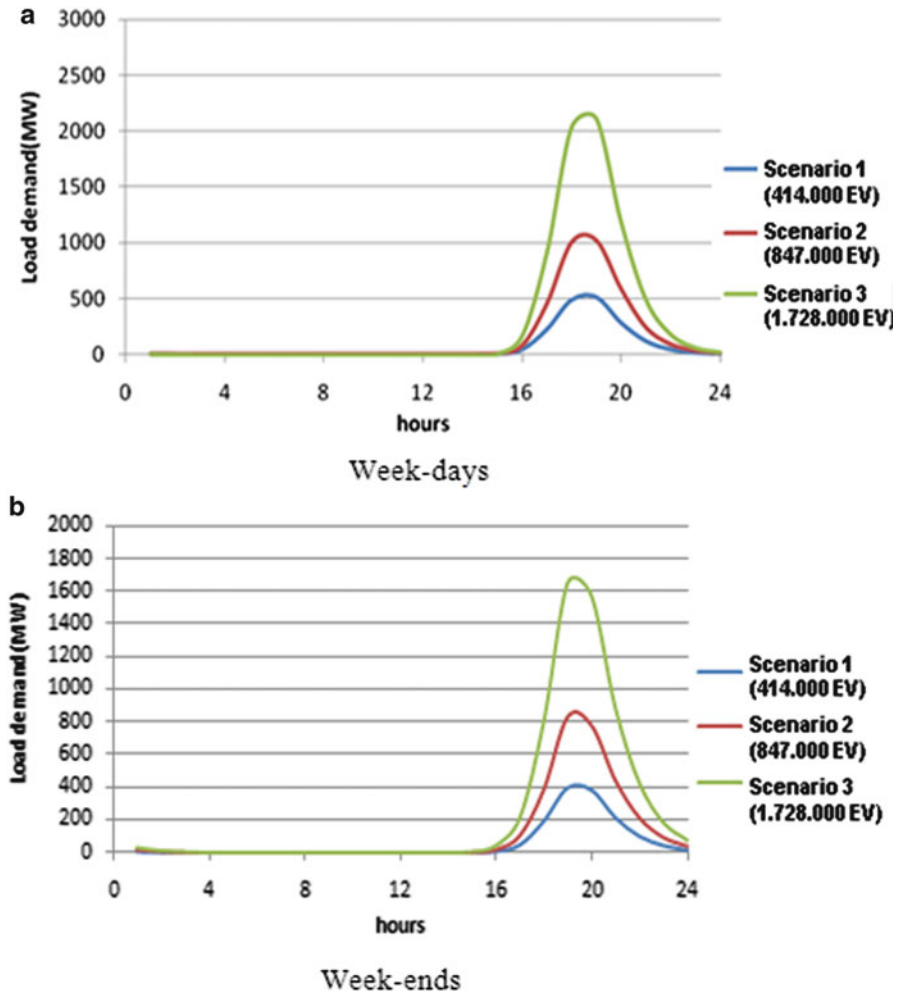


Fig. 3.6 Dumb charging—EV Load (Germany)

### Dumb Charging—Workplace Chargers

In the previous scenarios, the EV owner was assumed to charge its EV only when returning home (single connection). In this scenario, the EV owner is offered the possibility to charge his EV elsewhere, for example, in a workplace (multiple connections). Figure 3.9 displays the EV charging demand for the three models of Table 3.2 for the optimistic EV penetration scenario (847,000 EV). Part of the daily EV charging needs can be fulfilled during morning hours at workplace, when the system demand is still relatively low. As the number of EV charging at workplaces increases, the additional system peak demand due to dumb charging reduces.

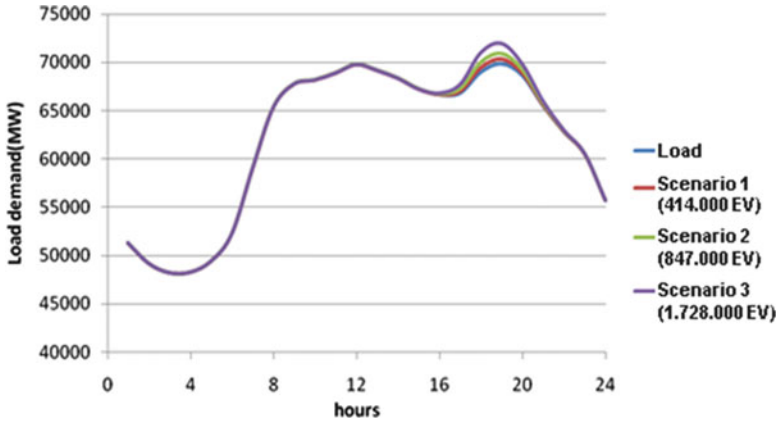


Fig. 3.7 Dumb charging—winter system demand diagram (Germany)

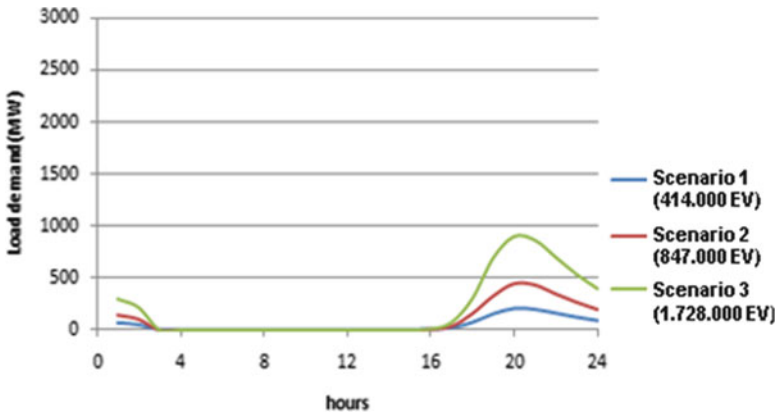


Fig. 3.8 Dumb charging—with battery SOC threshold (Germany)

The additional energy requirements of EV charging for the three models are 3,651.21 MWh, 3,782.14 MWh, and 3,913.06 MWh, respectively. The energy requirements of dumb charging with home/work connections are slightly increased compared with the ones of dumb charging (scenario 2). This can be justified by the fact that the morning charging enables PHEV to travel longer distances in battery mode during a day, since they are recharged after the first trip.

Figure 3.10 shows the annual system load diagram for Germany, including the EV charging requirements including weekdays and weekends.

### 3.3.1.2 Multi-tariff Scheme

Several energy providers offering different tariff schemes are active in the German energy market. Although it is not easy to represent all low tariff signals by a single

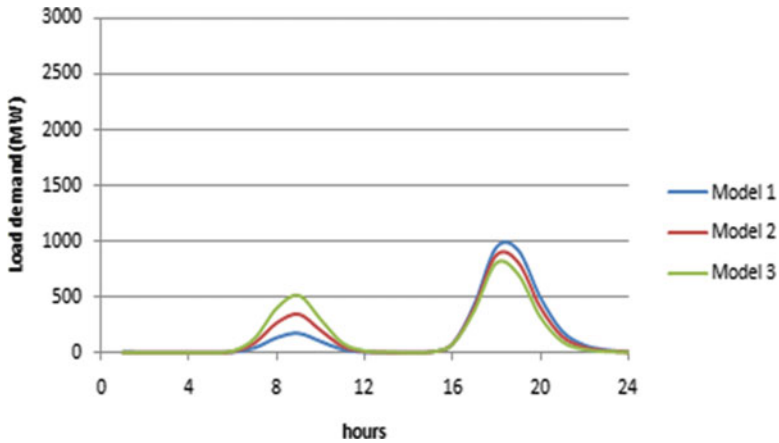


Fig. 3.9 Dumb charging with Home/Work charging-EV Load (Germany)

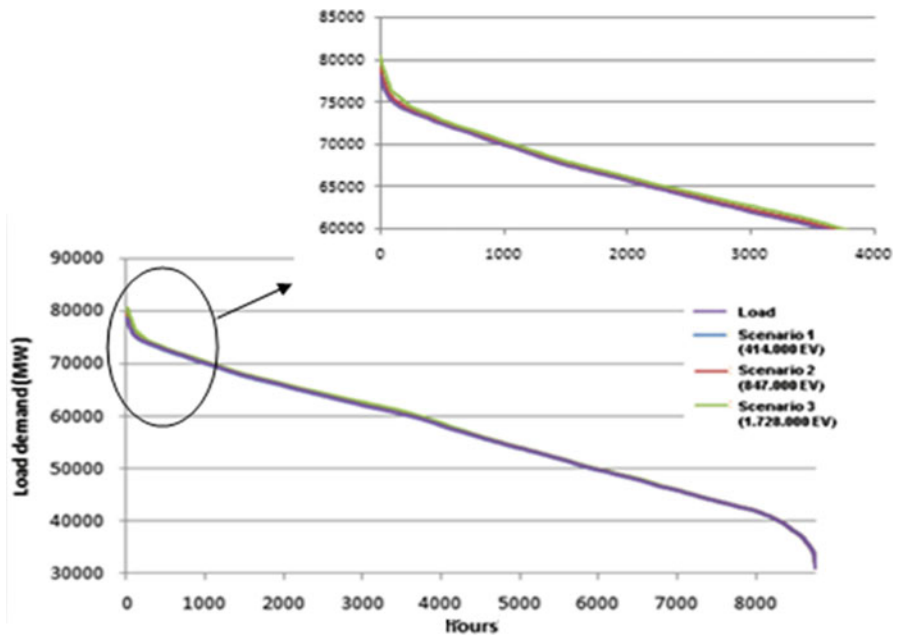


Fig. 3.10 Annual system load curve for dumb charging (Germany)

pattern, the majority of energy providers offer low tariffs during 22:00–06:00. The following analysis is based on a dual-tariff scheme, as follows:

- Winter Period (1/11–30/4): Low Charging: (22:00–06:00)
- Summer Period (1/5–30/10): Low Charging: (22:00–06:00)

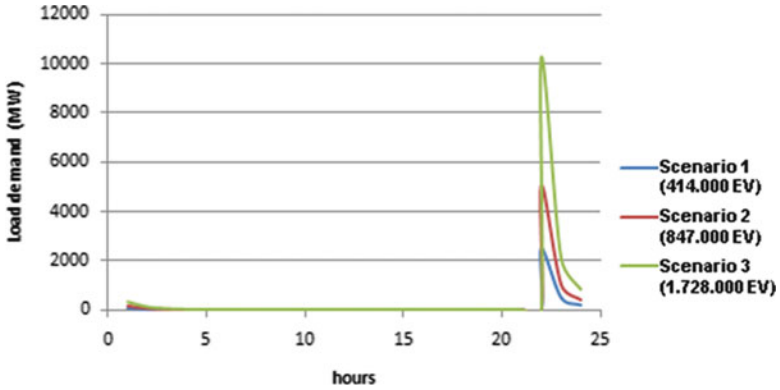


Fig. 3.11 Dual-tariff EV charging demand (Germany)

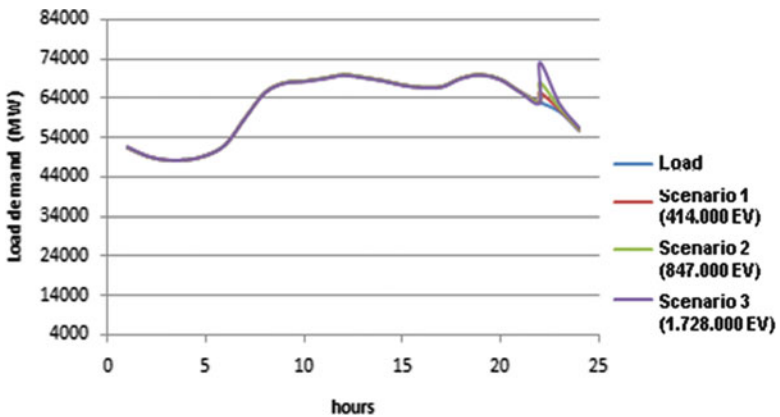


Fig. 3.12 Dual-tariff charging—winter system demand diagram (Germany)

Figure 3.11 presents the additional EV charging demand taking into account the tariff scheme and the restriction that EV can be charged only at home. According to the EV penetration scenarios, the additional energy requirements are 1,735 MWh, 3,532 MWh, and 7,190 MWh, respectively. The dual-tariff scheme results in an instantaneous increase in EV demand at the beginning of the period of low energy prices. The total amount of energy served is equal to the case of simple dumb charging; however, EV charging appears now completely synchronized.

Figure 3.12 presents the modified system load curve during a typical winter day. As the EV penetration level increases, the impact on the system demand becomes more serious. In the aggressive scenario, the synchronized EV charging results in a new peak demand, larger than the system’s daily peak. This happens because the low pricing period starts while the system demand is relatively high.

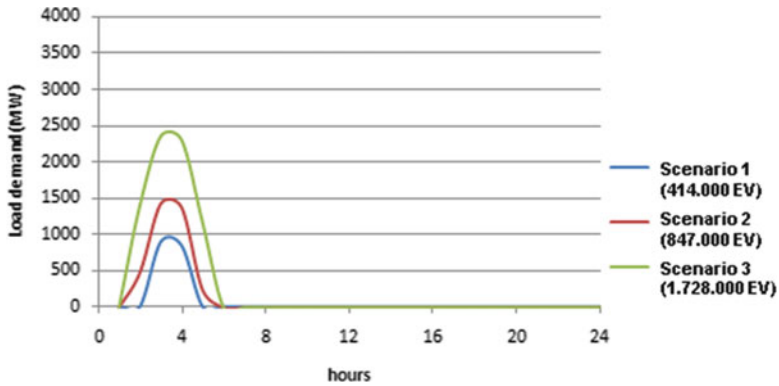


Fig. 3.13 Smart charging—EV demand (Germany)

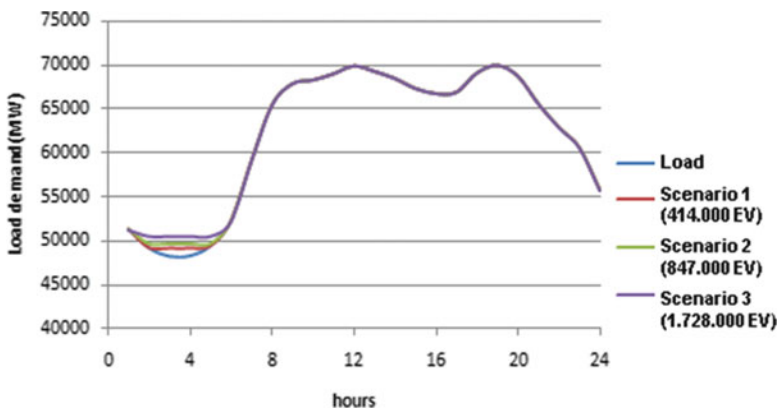


Fig. 3.14 Smart charging—winter system load diagram (Germany)

### 3.3.1.3 Smart Charging

The main idea of the adopted charging approach is to manage the EV load in a way that minimizes the total load variation.

Figure 3.13 shows the additional charging demand for the three penetration scenarios. Comparing the peak EV demand in case of smart charging with the previous charging concepts, it can be seen that the peak during smart charging is almost 1/4 of the peak of dual-tariff charging, but higher than the peak of dumb charging. However, the EV demand in smart charging is distributed effectively among the off-peak hours, improving the system load factor (Fig. 3.14).

Figure 3.15 presents the modified annual system load diagram considering the additional energy demand under the smart charging concept. Contrary to the system demand curve of dumb charging, smart charging EV demand increases the base load.

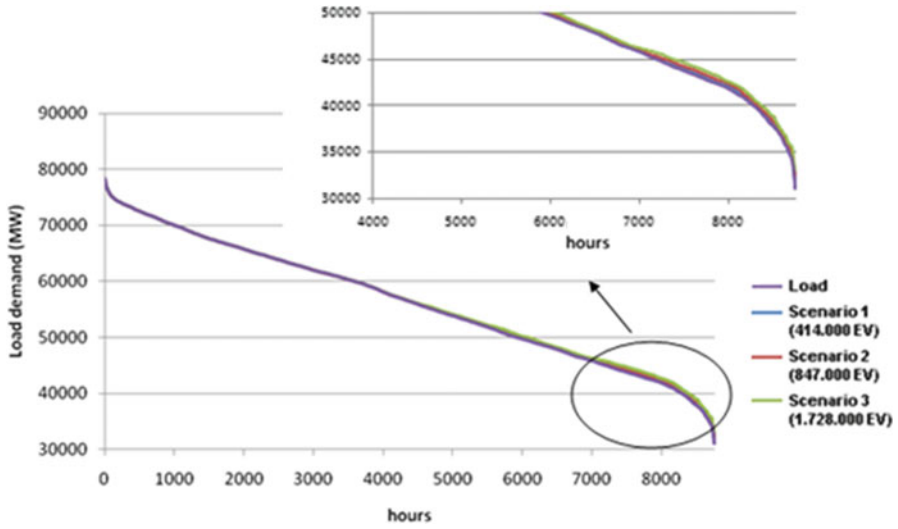


Fig. 3.15 Impact of EV smart charging in the system annual demand curve (Germany)

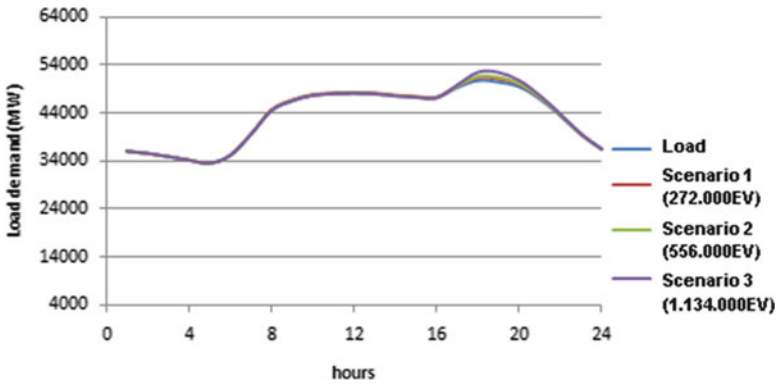


Fig. 3.16 Dumb charging—winter system demand diagram (UK)

### 3.3.2 UK

#### 3.3.2.1 Dumb Charging

The impact of EV on the daily system demand, in case of dumb charging, is shown in Figs. 3.16 and 3.17. During winter time, the daily peak increases by 0.89%, 1.79%, and 3.69%, for the three penetration levels, respectively. Even though summer load demand is characterized by a peak demand during midday hours, the EV charging demand of the aggressive scenario is high enough to create a new daily system peak at afternoon hours when people return home.



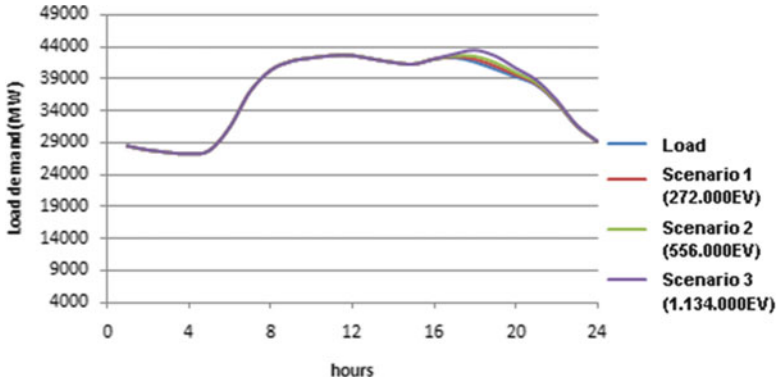


Fig. 3.17 Dumb charging—summer system demand diagram (UK)

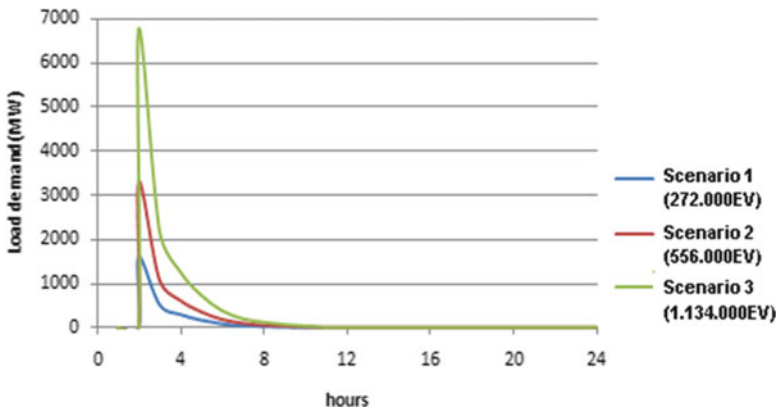


Fig. 3.18 Dual-tariff EV charging demand (UK)

### 3.3.2.2 Multi-tariff Scheme

The Electricity 7 scheme is used for the multi-tariff analysis. Economy 7 is the name of a differential tariff provided by U.K. electricity suppliers that provides cheap off-peak electricity offers based on the costs of base load generation. The times when Economy 7 applies vary among different regions and seasons. The dual-tariff adopted in this case is as follows:

- Winter Period (1/11–30/4): Low Charging: (24:30–07:30)
- Summer Period (1/5–30/10): Low Charging: (01:30–08:30)

Figure 3.18 presents the additional EV charging demand taking into account the tariff scheme and the restriction that EV can be charged only at home. According to the EV penetration scenarios, the additional energy requirements are 1,863 MWh, 3,848 MWh and 7,822 MWh, respectively.

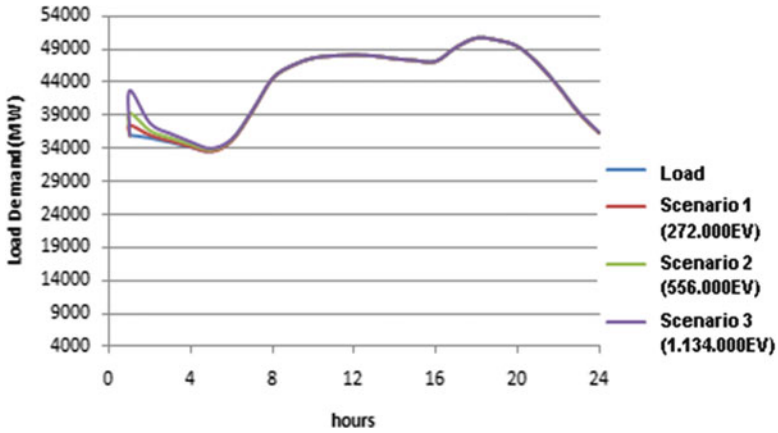


Fig. 3.19 Dual-tariff charging—winter system demand diagram (UK)

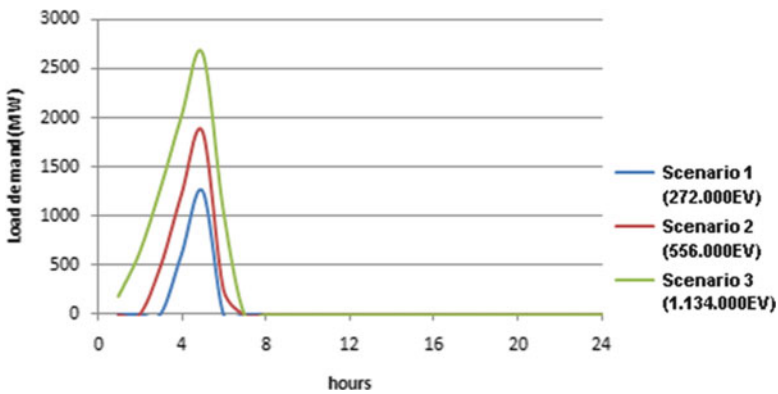


Fig. 3.20 Smart charging—EV demand (UK)

Figure 3.19 presents the modified system load curve in a typical winter day. As the EV penetration level increases, the impact on the system demand becomes more serious.

### 3.3.2.3 Smart Charging

Figures 3.20 and 3.21 show the additional charging demand for the three penetration scenarios under the smart charging concept.

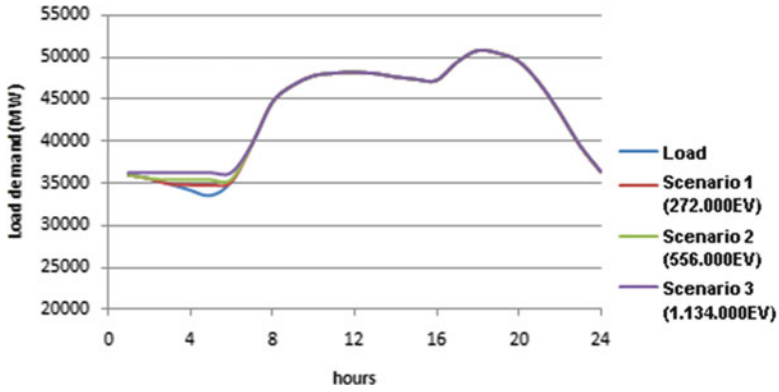


Fig. 3.21 Smart charging—winter system load diagram (UK)

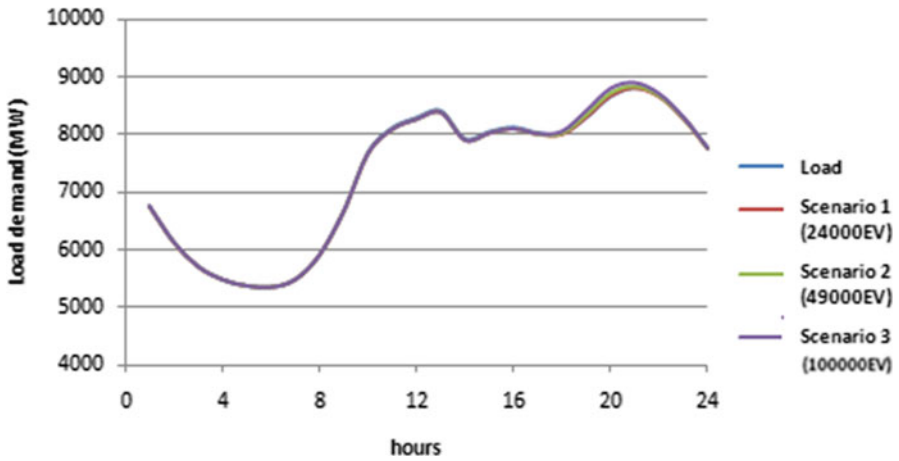


Fig. 3.22 Dumb charging—winter system demand diagram (Portugal)

### 3.3.3 Portugal

#### 3.3.3.1 Dumb Charging

The impact of EV on the total daily system demand diagram is shown in Figs. 3.22 and 3.23. During winter time, the daily peak increases by 0.32%, 0.64%, and 1.32%, for the three penetration levels, respectively.

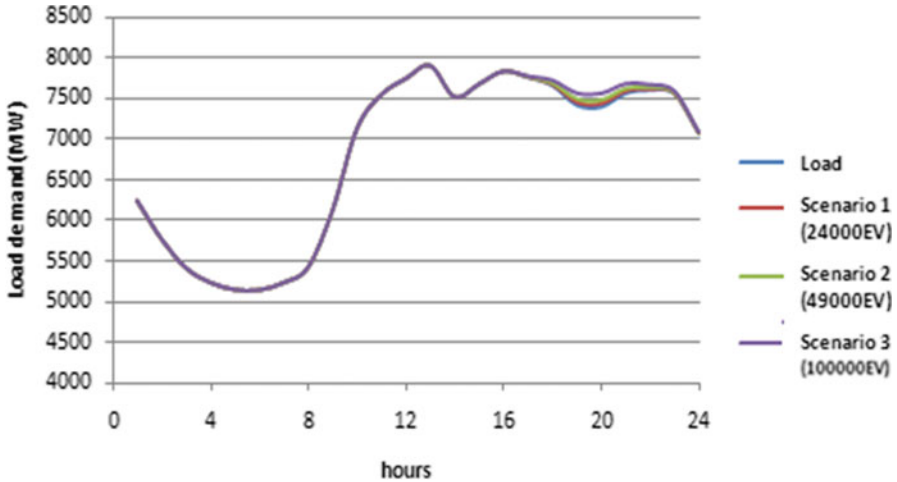


Fig. 3.23 Dumb charging—summer system demand diagram (Portugal)

### 3.3.3.2 Multi-tariff Scheme

In Portugal, the single operator (EDP) has established two dual-tariff policies:

1. Ciclo diario (Daily dual-tariff)
  - a. Winter Period (1/11–30/4): Low Charging: (22:00–07:00)
  - b. Summer Period (1/5–30/10): Low Charging: (22:00–07:00)
2. Ciclo semanal (Week dual-tariff)
  - a. Winter Period (1/11–30/4)
    - Weekdays Low Charging: (24:00–07:00)
    - Saturday Low Charging: (22:00–09:00)
    - Sunday Low Charging: all day
  - b. Summer Period (1/5–30/10)
    - Weekdays Low Charging: (24:00–07:00)
    - Saturday Low Charging: (22:00–09:00)
    - Sunday Low Charging: all day

Figure 3.24 shows the additional EV charging demand taking into account the “Ciclo diario” and the restriction that EV can be charged only at home. The respective diagrams for the “Ciclo semanal” are presented in Fig. 3.25.

### 3.3.3.3 Smart Charging

Figures 3.26 and 3.27 show the additional charging demand for the three penetration scenarios under the smart charging concept.

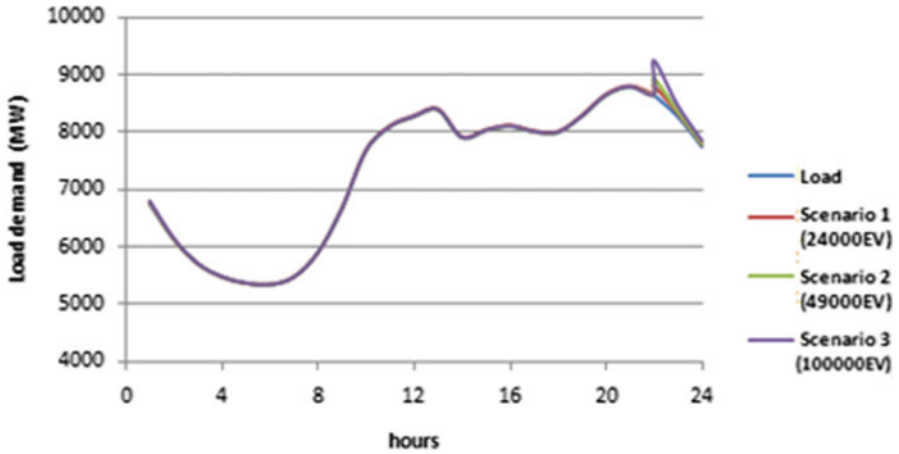


Fig. 3.24 “Ciclo diario”—winter system demand diagram (Portugal)

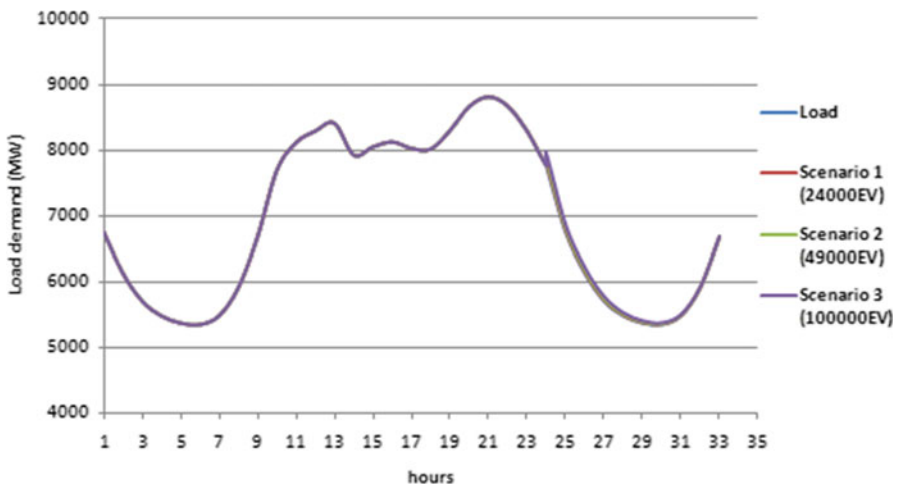


Fig. 3.25 “Ciclo semanal”—winter system demand diagram (Portugal)

### 3.3.4 Spain

#### 3.3.4.1 Dumb Charging

The impact of EV fleet on the total daily system demand diagram is shown in Figs. 3.28 and 3.29. During winter time, the daily peak increases by 0.54%, 1.12%, and 2.32%, for the three penetration levels, respectively.

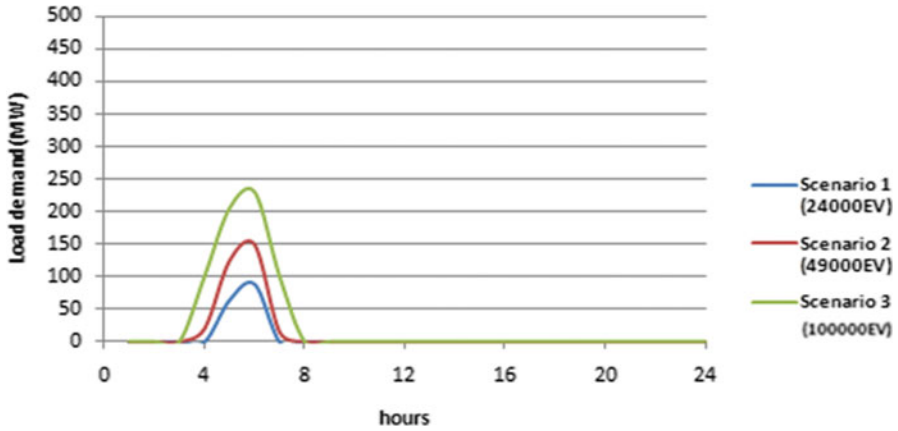


Fig. 3.26 Smart charging—EV demand (Portugal)

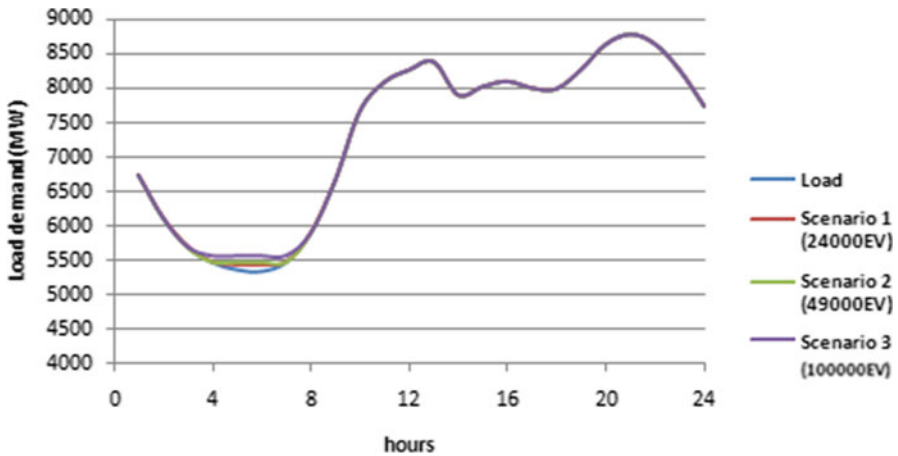


Fig. 3.27 Smart charging—winter system demand diagram (Portugal)

### 3.3.4.2 Multi-tariff Scheme

The dual-tariff scheme of Iberdrola is studied here:

- Winter Period (1/11–30/4): Low Charging: (22:00–12:00)
- Summer Period (1/5–30/10): Low Charging: (23:00–12:00)

Figure 3.30 presents the additional EV charging demand taking into account the tariff scheme and the restriction that EV can be charged only at home. According to the EV penetration scenarios, the additional energy requirements are 798 MWh, 1,629 MWh, and 3,315 MWh, respectively. Figure 3.31 presents the modified system load curve on a typical winter day.

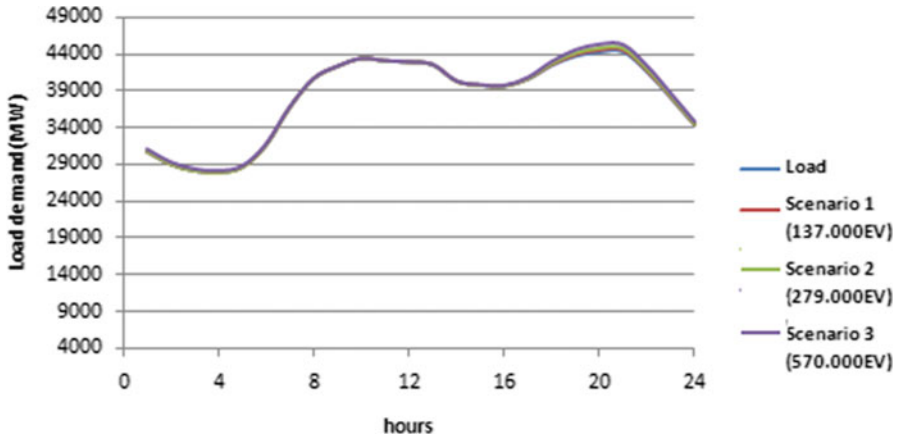


Fig. 3.28 Dumb charging—winter system demand diagram (Spain)

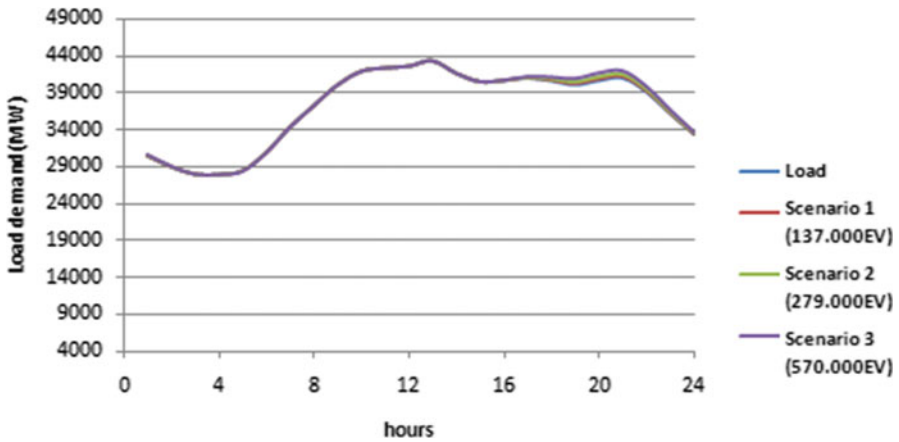


Fig. 3.29 Dumb charging—summer system demand diagram (Spain)

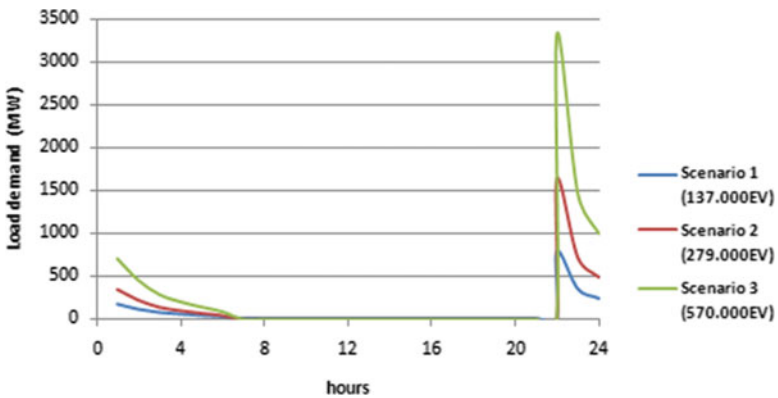


Fig. 3.30 Dual-tariff EV charging demand (Spain)

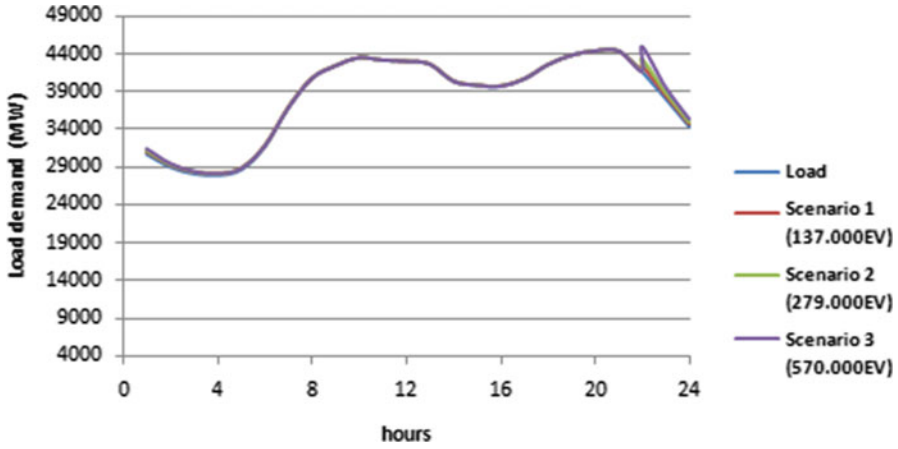


Fig. 3.31 Dual-tariff charging—winter system demand diagram (Spain)

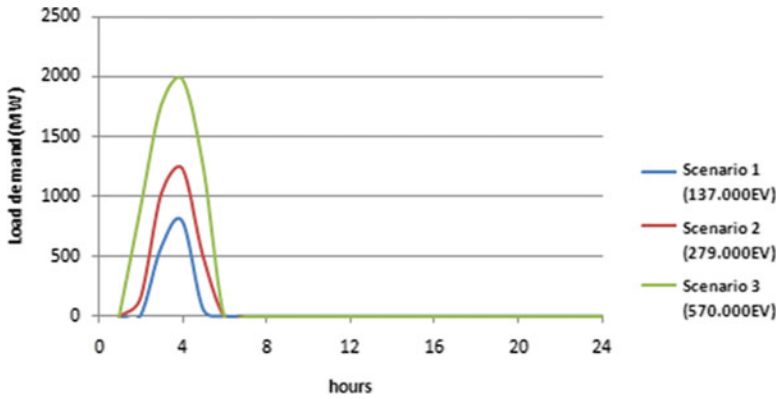


Fig. 3.32 Smart charging—EV demand (Spain)

### 3.3.4.3 Smart Charging

Figures 3.32 and 3.33 show the additional charging demand for the three penetration scenarios under the smart charging concept.

## 3.3.5 Greece

### 3.3.5.1 Dumb Charging

The impact of EV on the total daily system demand is shown in Figs. 3.34 and 3.35. During winter time, the daily peak increases by 0.51%, 1.02%, and 2.13%, for the



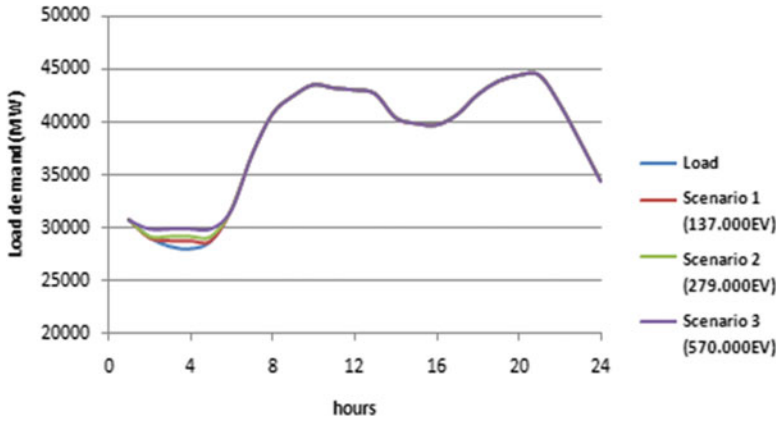


Fig. 3.33 Smart charging—winter system demand diagram (Spain)

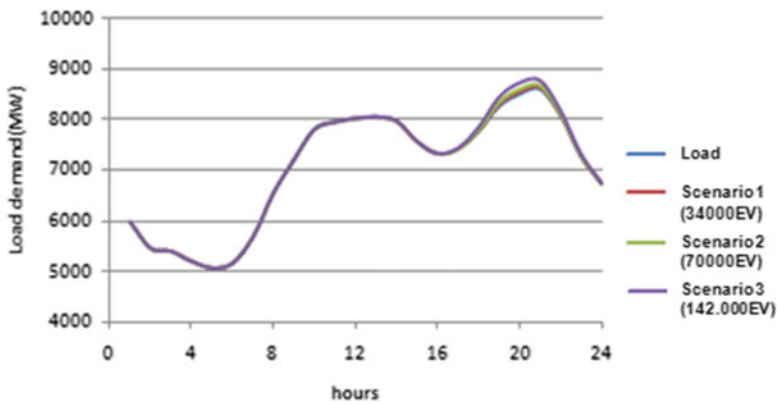


Fig. 3.34 Dumb charging—winter system demand diagram (Greece)

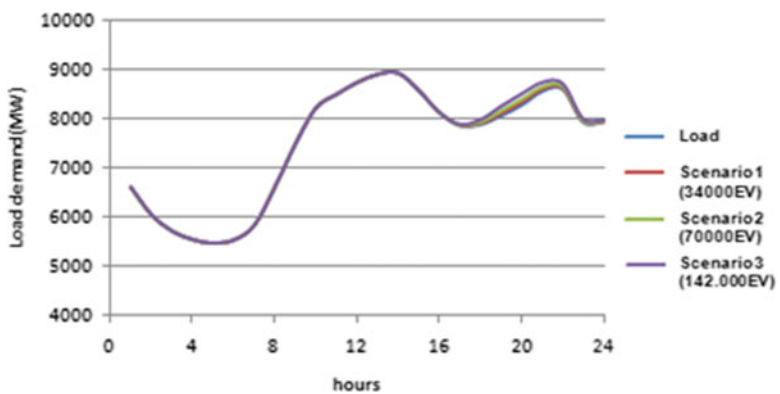


Fig. 3.35 Dumb charging—summer system demand diagram (Greece)

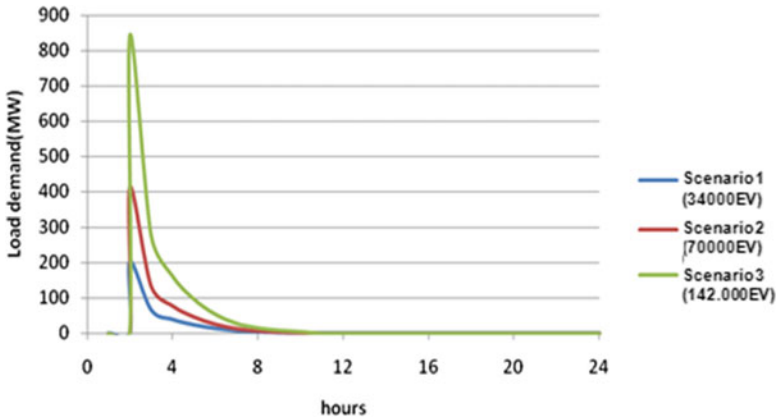


Fig. 3.36 Dual-tariff EV charging demand (Greece)

three penetration levels, respectively. Summer load demand is characterized by a peak demand during midday hours. Even in the aggressive deployment scenario, the EV charging demand is not high enough to create a new daily system peak at afternoon hours.

### 3.3.5.2 Multi-tariff Scheme

The dual-tariff scheme adopted in Greece by PPC is as follows:

- Winter Period (1/11–30/4): Low Charging: (2:00–08:00 and 15:30–17:30)
- Summer Period (1/5–30/10): Low Charging: (01:30–08:30)

Figure 3.36 presents the additional EV charging demand taking into account the tariff scheme and the restriction that EV can be charged only at home. According to the EV penetration scenarios, the additional energy requirements are 236 MWh, 485 MWh, and 995 MWh, respectively.

Figure 3.37 presents the modified system load curve on a typical winter day.

### 3.3.5.3 Smart Charging

Figures 3.38 and 3.39 show the additional charging demand for the three penetration scenarios under the smart charging concept.

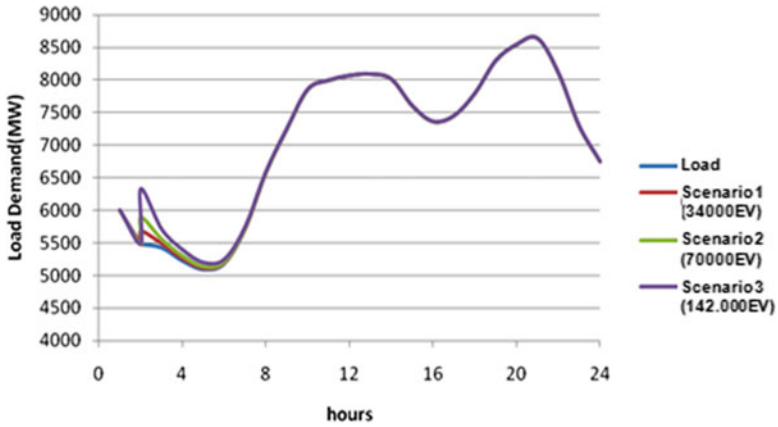


Fig. 3.37 Dual-tariff charging—winter system demand diagram (Greece)

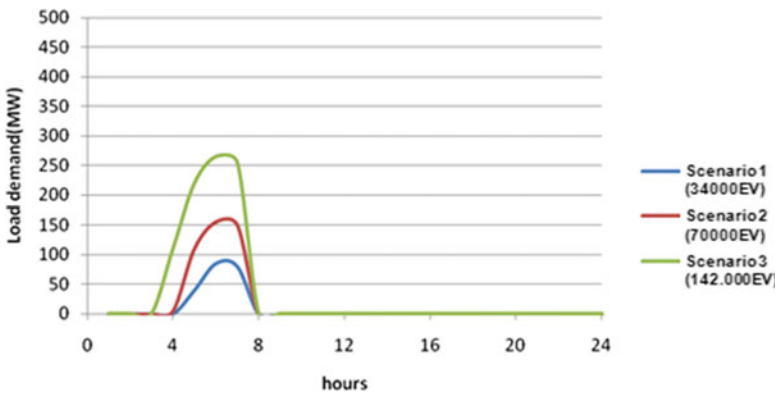


Fig. 3.38 Smart charging—EV demand (Greece)

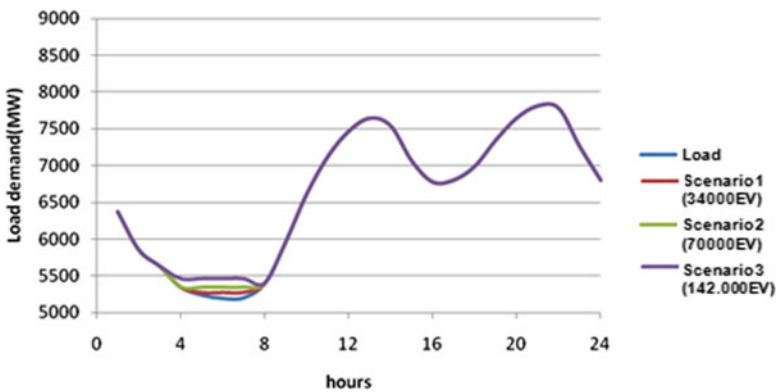


Fig. 3.39 Smart charging—winter system demand diagram (Greece)

### 3.4 Conclusions

In the previous sections, the additional energy requirements that fulfill EV charging needs have been identified, and their impact on the daily and annual system demand diagram of five European countries has been analyzed considering different charging modes and different traffic patterns of drivers, i.e., daily travel distance, time of plug-in, charging rate, and EV battery usage per kilometer.

Based on this analysis, the dumb charging mode can lead to “worst case” scenarios. When EV charging remains completely uncontrolled, the profile of the charging demand is highly dependent on the time of return from the last journey of the day. Since home arrival normally coincides with increased residential consumption, the EV demand can be synchronized with the system peak load. Thus, dumb charging might result in local distribution network congestions and a higher share of EV might require premature grid investments. Figure 3.40 shows the impact of the “dumb charging” in the system daily demand in different European countries and for various EV penetration scenarios. The worst-case scenario on a typical winter day is presented.

The grid impacts of home charging can be limited by developing charging infrastructures at workplaces. In this case, part of the daily EV charging needs compensating the battery consumption for driving from home to work can be fulfilled during morning hours at workplace, when the system demand is still relatively low. As the number of EV charging at workplaces increases, the additional system peak demand due to EV “dumb charging” reduces.

Dual-tariff charging is more effective than dumb charging, since it enables the shifting of the EV demand from high loading hours to off-peak hours. However, this

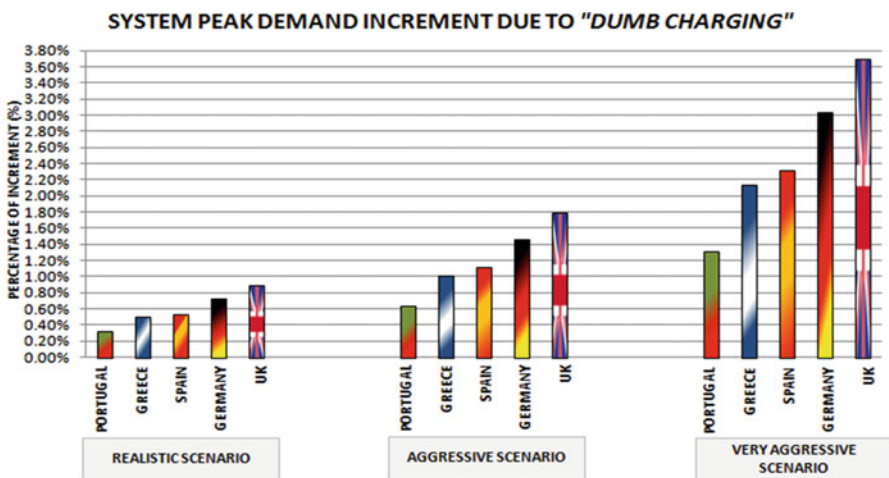
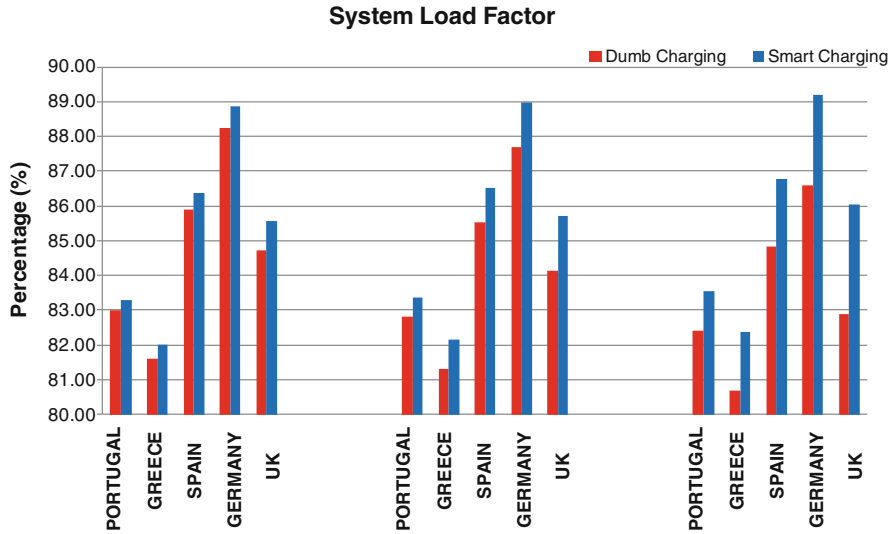


Fig. 3.40 The increase in system peak demand in different European countries due to “dumb charging” for the three penetration scenarios



**Fig. 3.41** The increase of system load factor comparing “dumb charging” with “smart charging”

is likely to result in a sharp increase in EV demand at the beginning of the low energy price period which might affect the network operation.

Smart charging avoids high peak loads by allocating the EV demand during off-peak hours. Figure 3.41 illustrates the effect of this load allocation to the system load factor. In smart charging, EV demand is managed in a way that reduces the system load variation between off-peak hours and high load hours. Smart charging is the most effective charging strategy; however, its implementation is not straightforward and for a large number of vehicles, it requires advanced control and management techniques.

## References

1. MERGE Deliverable WP3\_Task3.2(I), Part I of Deliverable 3.2, “Evaluation of the impact that a progressive deployment of EV will provoke on electricity demand, steady state operation, market issues, generation schedules and on the volume of carbon emissions-electric vehicle penetration scenarios in Germany, UK, Spain Portugal and Greece,” 21 Feb 2011
2. European Commission (2009) Mobility and transport. Road safety: vehicle categories [online]. [http://ec.europa.eu/transport/road\\_safety/vehicles/categories\\_en.htm](http://ec.europa.eu/transport/road_safety/vehicles/categories_en.htm)
3. MERGE Deliverable D1.1: “Specifications for EV-grid interfacing, communication and smart metering technologies, including traffic patterns and human behaviour descriptions,” 24 Aug 2010. <http://www.ev-MERGE.eu/>
4. European Network of Transmission System Operators for Electricity (2010) Hourly load values of a specific country for a specific month. Consumption Data [online]. <http://www.entsoe.eu/index.php?id=92>